Trees, People and the Built Environment II
Urban Trees Research Conference, University of Birmingham, UK (2014)

Extreme arboriculture

lessons from transplanting mature street trees

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Tree Transplanting in Hong Kong

1200 trees a year are transplanted in Hong Kong

Street trees are commonly transplanting to preserve the Territory's green heritage.
Typical size:

Height : 3-17m (ave. 7.2m)
DBH : 150-1500mm (ave. 320mm)

- Some way beyond the range of standard commercially grown trees
- Growing in very difficult environments.

This form of arboricultural practice offers an opportunity to understand more about mature trees in our urban streets.

Transplanting

Existing knowledge

Our understanding of the tree responses to transplanting is based on extensive research on field grown nursery trees.

Urban street trees , in addition to be older, can have significant morphological characteristics resulting from their constrained growing environments.

Their response to transplanting likely to be different.

Images: Kijiji.ca, Bali.org.uk

Transplanting
Shock

Extended period of slow growth, in which the tree may exhibit signs of dieback, reduced foliage, shorter twig and root elongation.

Transplant shock results from water stress / imbalance, caused by loss of water absorbing root capacity.

Shock goes on until the balance is restored.

A tree’s response is typically to try and correct water imbalance, by growing new roots and minimizing water loss.

Cassia surratensis *in shock after transplanting*

Transplanting Trees
Root Pruning

Root pruning prior to transplanting increases the chances of survival. Pruning generate new (fine) water absorbing roots close to the trunk which are then captured in the root ball when transplanted.

New roots also increase storage capacity for carbohydrate required for re-growth.

Transplanting Trees
Root ball ratio

Root ball ratio = root ball diameter in relation to trunk diameter.

Ratio for largest field grown nursery trees in USA and UK Standards is (10:1).

Issue of 'weight' vs 'root capture'.

Root ball depth, usually specified as 60% of the root ball diameter for small trees.

With the majority of roots in the upper layers, there is limited value in the root ball being deeper than 1200mm.

HK guidelines suggest max depth of only 900mm.

Transplanting Trees
Crown Pruning

Crown pruning reduces potential water loss, and can help maintain water balance, offsetting loss of water absorption capacity from root pruning.

Extent of crown pruning recommended to be kept to a minimum (<25% at most).

Side effects of crown pruning include:

- reduced photosynthate production
- potentially slower root growth.

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Transplanting Trees
Tree responses to root and canopy pruning

- Allocate resources in response to stress
- Favour production of new roots over production of new shoots, but
- May replenishing carbohydrate stores before growth.

Bombax ceiba

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Transplanting Trees

When to transplant

Timing of root pruning and lifting operations in relation to:

•Periods of active shoot growth
•Periods of root elongation
•Soil temperature, moisture.

Survival / recovery time:

•Varies according to species - some tree species are better adapted to transplanting
•Dependent on many other factors.

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Street Trees

Typically poor soil environment in Hong Kong

- Limited soil volume
- Low levels of nutrients, organic matter, soil organisms etc.
- High degree of compaction
- Poor aeration
- Poor water movement / drainage.

Some of the root conditions were due to poor planting practices in the past.

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Street Trees

Limited canopy space

Canopy space limited by buildings and above ground structures, vehicle movement, sightlines.

Street Trees

Tree responses to poor growing environment

Road side locations generate particular morphological responses in street trees that may facilitate transplanting:

•shallow rooting
•restricted root spread, narrowly defined zone of rapid root taper
•high root density, concentration of root biomass / water absorbing roots around the trunk.

•narrow crowns
•smaller crown volume (balance limited roots mass).

Trees are tolerant of pollution and physical abuse or they die. Average life expectancy of a HK street tree believed to be <20 years.

Study of Street Tree Transplanting in Hong Kong

Transplanting Operations (2010 to 2011) for 1000 urban street trees

Common native and exotic species:

•height 3.0 - 14.0m
•trunk diameter (dbh) 0.1 - 0.7m
•crown spread 2.5m - 10.0m

Growing in roadside pavement pits (with root barriers) or in narrow raised planters (1.0 - 1.5m wide).

Transplanted to off-site planting locations.

Transplanting Operations
Transplanting process

Three stage root pruning process:
i.root pruning trenches dug and backfilled on two sides,
ii.repeat for the other two sides
iii.undercut and lifted.

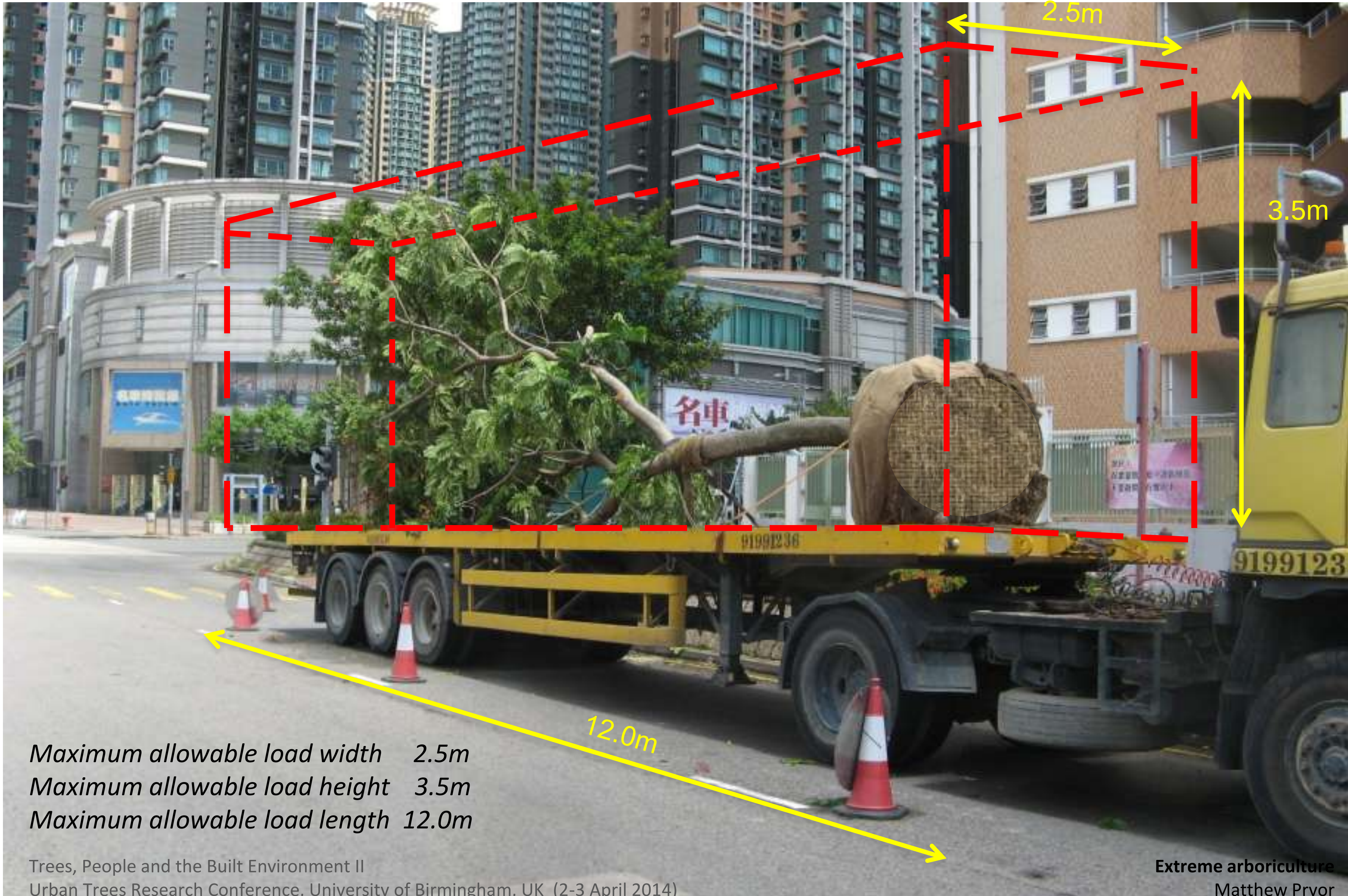
Pruning interval varied with trunk diameter (0 to 6 months).

Root balls 800-1000mm deep, wrapped in hessian and wired.

Transplanting Operations

Transport Limitations

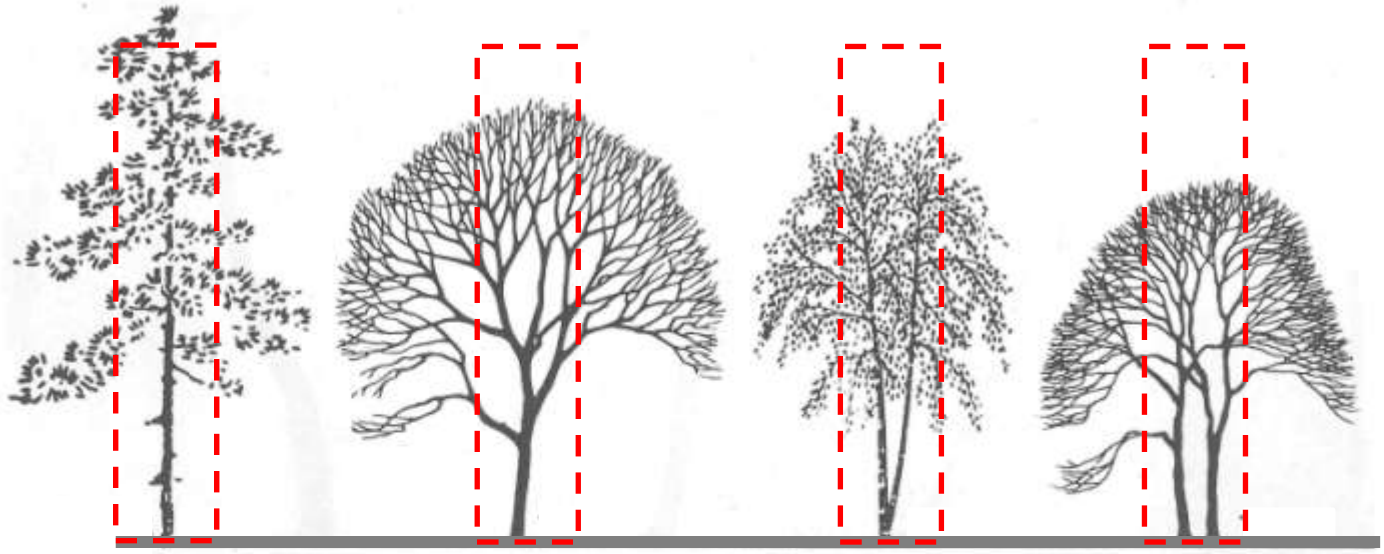
Road traffic regulations meant that root ball, trunk and canopy need to be physically reduced (by pruning or wrapping)

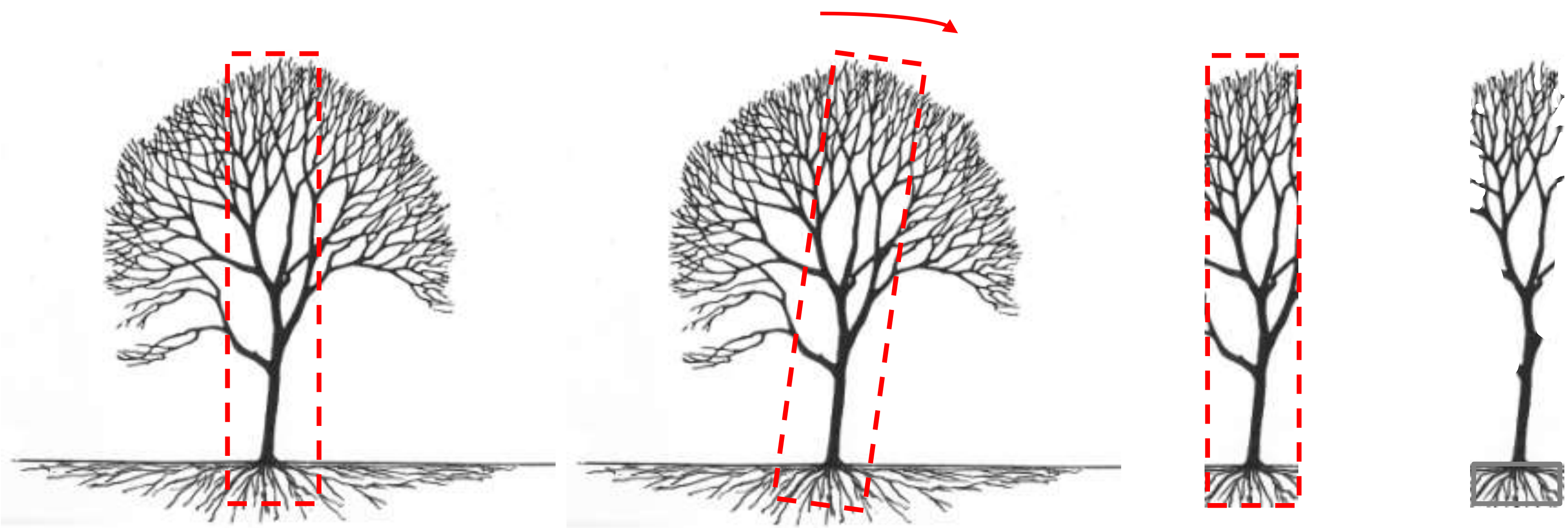


Transplanting Operations
Canopy reductions

What of the original tree is it possible to fit (cut or bend) inside the box ?

How far will the form and health of the tree be compromised by doing so ?





Transplanting Operations

Crown pruning street trees to allow for transportation

Rigid branching structure of mature trees results in a significant proportion of the crown (average 38.5%) having to be removed to facilitate road transportation.

Branching structure of some species can be severely compromised in the process (e.g. *Bombax ceiba*).

Large diameter pruning cuts (up to 250mm dia.) made them vulnerable to termite attack and fungal infection.

Impact on internal water balance, and potential for re-growth.

Transplanting Operations
Transportation

Trees lifted by straps wrapped around the root ball, with a further guide strap attached at mid trunk.

Tree crowns were wrapped, laid horizontally on trucks, padded and securely tied.

Transported approx. 20km by road to two temporary receptor sites.

Transplanting Operations

Physical impacts during transplanting

Disruption of root-soil interface by vibration.

Wounding by:
Cutting, tearing, twisting, compression.

Transplanting Operations
Re-establishment

Trees set approx. 5.0m spacing, in above-ground geofabric lined wire mesh planter boxes 1000 high and 200-500mm wider than the root ball. Trees were guyed to ensure stability in high wind.

Arboricultural aftercare during the holding period, including daily irrigation, weeding, mulching, fertilizing, and topical disease and pest control.

Holding area facilitated monitoring of tree responses to transplanting:

•easier access to the canopy
•opportunities to examine root growth at the planter edge and underneath without disturbing the tree
•ensured free drainage of the root ball mulch retained over the root ball, and competition from weeds minimised
•allowed control on soil moisture (by irrigation) specific to each tree
•targeted application of fertilizers and pest control measures.

Research Study

Transplanting variables

Ficus microcarpa

Variables related to the characteristics of the tree

- **Species**
- **Overall tree height** (m), in one metre intervals
- **Trunk diameter** (m), as a proxy for age in 0.10m intervals
- **Original health condition** of the tree prior to transplanting (good / fair / poor) based on original tree survey
- **Original form** of the tree prior to transplanting (good / fair / poor) based on original tree survey.

Variables in the condition of the donor site

- **Soil type** (silty clay, silty loam, sandy loam)
- **Tree position** (pavement pit, raised planter, open ground).

Research Study
Transplanting variables

<u>Variables related to the specific transplanting operation</u>

- **Reduction in crown volume** resulting from pruning (%), (estimated based on before / after photos)
- **Root ball ratio,** banded in range between 3:1 and 13:1
- **Root ball depth (mm),** banded in 100mm intervals
- **Time of year of first root pruning**, categorised within two month interval periods, (e.g. Jan-Feb)
- **Time interval between root pruning** exercises (0-6 months)
- **Time of year of transplanting** operation categorised within two month interval periods, (e.g. Jan-Feb)
- **Skill and care exercised** in the transplanting and aftercare operations.

Research Study

Transplanting outcomes – success / failure

Success = tree over coming shock and making a full return to normal growth pattern.

Key metric for transplant shock was reduced twig elongation (compared to control specimens at both donor and receptor sites).

Transplant shock or death was categorised into 12 month periods (whole growing season).

Other symptoms of shock were monitored:

•average shoot length
•average leaf length
•volume of new foliage
•canopy die back (%)
•root growth and elongation
•budding, flowering and fruiting patterns.

Measurement of twig elongation against control specimens of comparable age and growing condition for each species (~ 350-750mm). Trees in shock typically had <100mm growth.

Form of *Bombax ceiba* trees heavily affected by canopy pruning for transplanting.

Research Study

Four species with more than 50 specimens identified for detailed study

Bombax ceiba,
Cotton Tree (59 specimens)

Ficus benjamina,
Weeping Fig (60)

Ficus microcarpa,
Chinese Banyan (132)

Melaleuca quinquenervia,
Paperbark Tree (117)

All common street tree species in Hong Kong.

Research Study
Overall response

Majority of trees experienced some form of transplant shock.

Small number of trees displayed no signs of transplant shock and grew normally directly after replanting.

Research Study
Overall response

Trees categorised (in 12 month periods) as:
- died
- in terminal decline
- recovered

A few trees died within days of being moved.

Others died more slowly, entering into a period of transplant shock before sliding into terminal decline.

By the end of the third year no specimens were still just in transplant shock.

Research Study
Terminal decline

Evidenced by:

•significantly reduced tree vigour
•no new foliage growth
•increasing degree of crown dieback (gradual decline in canopy volume)
•desiccation / bark cracking
•no new root growth.

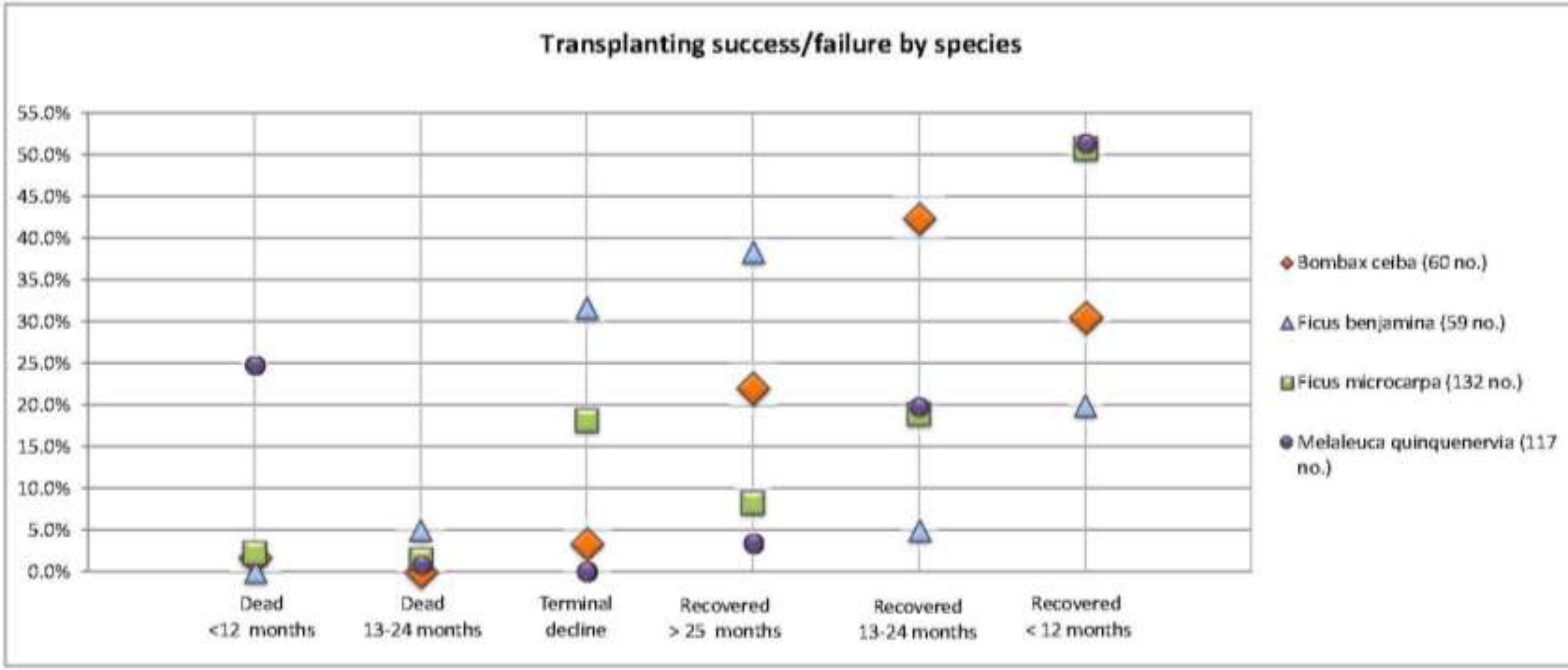
Often accompanied by incidents of insect attack and fungal infection (for which pest and fungal control measures were generally ineffective).

Trees in terminal decline after transplanting.

Research Study

Overall transplant success / failure (after 42 months)

85 trees (14.8%) failed, i.e. died or were in terminal decline.
486 trees (85.2%) had recovered from the transplant shock and regained normal growth pattern.



Frequency distribution chart

Bombax ceiba 3 of 59 failed (5.0%)
Ficus benjamina 22 of 60 failed (36.6%)
Ficus microcarpa 29 of 132 failed (21.9%)
Melaleuca quinquenervia 30 of 117 failed (25.6%).

Research Study
Statistical analysis

Correlation (Spearman) between variables and Success/Failure for four species.

Success/Failure	Transplanting Variables: Location	Height	Trunk Diameter	Form	Pruning Time	Pruning interval	Transplanting Time	Root Ball Ratio	Extent of Crown Pruning
Bombax ceiba	0.141	-0.162	-0.276*	0.128	-0.307*	-0.030	-0.268*	0.171	-0.129
Ficus benjamina	0.542**	-0.534**	0.128	0.325*	-0.417**	0.463**	0.017	-0.222	-0.230
Ficus microcarpa	-0.327**	-0.205*	0.115	0.179*	0.358**	-0.015	-0.149	0.132	-0.039
Melaleuca quinquenervia	-0.440**	-0.387**	-0.217*	0.499**	0.512**	-0.575**	-0.416**	0.016	-0.096

Spearman analysis
* Correlation significant at the 0.05 level (2-tailed);
** Correlation is significant at the 0.01 level (2-tailed)

Research Study

Analysis of correlation between transplant variables and success/failure

- **Location,** had a significant correlation with transplant success/failure for each species except *Bombax ceiba,* (only 3 failures within the set so results were not clear).

- **Height,** had a significant negative correlation with transplant success/failure for *Ficus benjamina* and *Melaleuca quinquenervia (*taller trees are more likely to fail), and a weak correlation for the other two species.

- **Trunk diameter,** had only a weak negative correlation with transplant success/failure for *Ficus benjamina* and *Melaleuca quinquenervia*, (larger trees are more likely to fail), but not for the other two species.

- **Form,** had a strong positive correlation with transplant success/failure, for *Melaleuca quinquenervia*, and to a lesser extent with *Ficus benjamina* and *Ficus microcarpa*, suggesting that poor form is better for transplanting success. This is discounted as the data distribution is very heavily skewed, with the large majority of the trees originally selected for transplanting being of 'good' form.


Ficus benjamina

Research Study

Analysis of correlation between transplant variables and success/failure

- **Pruning time**, significant correlation with transplant success/failure for each of the species, but within different time periods.

- **Pruning interval**, significant correlation with transplant success/failure for *Ficus benjamina* (longer interval better for survival). *Melaleuca quinquenervia* also showed a significant negative correlation (shorter interval is better for survival). The data set for this species latter was affected by the failure of one set of large specimens due to other factors.

- **Time of transplanting**, significant negative correlation with transplant success/failure only for *Melaleuca quinquenervia*, and to a lesser extent for Bombax ceiba. The earlier part of the year (Mar – Apr) being better for success except *Ficus benjamina*.

- **Root ball ratio**, no significant correlation with transplant success/failure. Given that the actual root ball ratio achieved varied considerably (as opposed to the proportionate size specified), the results suggest that root ball size is not a key factor in determining transplant success/failure.

- **Extent of crown pruning**, weak negative correlation with transplant success/failure (i.e. less canopy reduction the more chance of survival). This is likely to reflect the relationship between the extent of canopy and root pruning, where maintaining a balance between the two may assist in minimizing water stress.

Research Study
Transplant success/failure in relation to species

Bombax ceiba, no strong correlation between transplanting success/failure and transplant variables.
•Slightly higher failure rate for larger trunk diameter specimens
•Better chance of success if pruning is undertaken in Jan – Feb, and if transplanting in Mar – Apr.

Ficus benjamina, strong correlation with location, height, pruning time and interval.
•Trees from raised planters and open ground more likely to survive
•Higher failure rate for taller specimens
•Better time for pruning Mar – Apr. Higher success with longer pruning interval
•Bigger trunk diameter does not affect survival rates.

Ficus microcarpa, strong correlation with location and pruning time.
•Trees from pavement pits more likely to survive
•Higher success if pruning is undertaken in Sep – Dec
•Bigger trunk diameter does not affect survival rates.

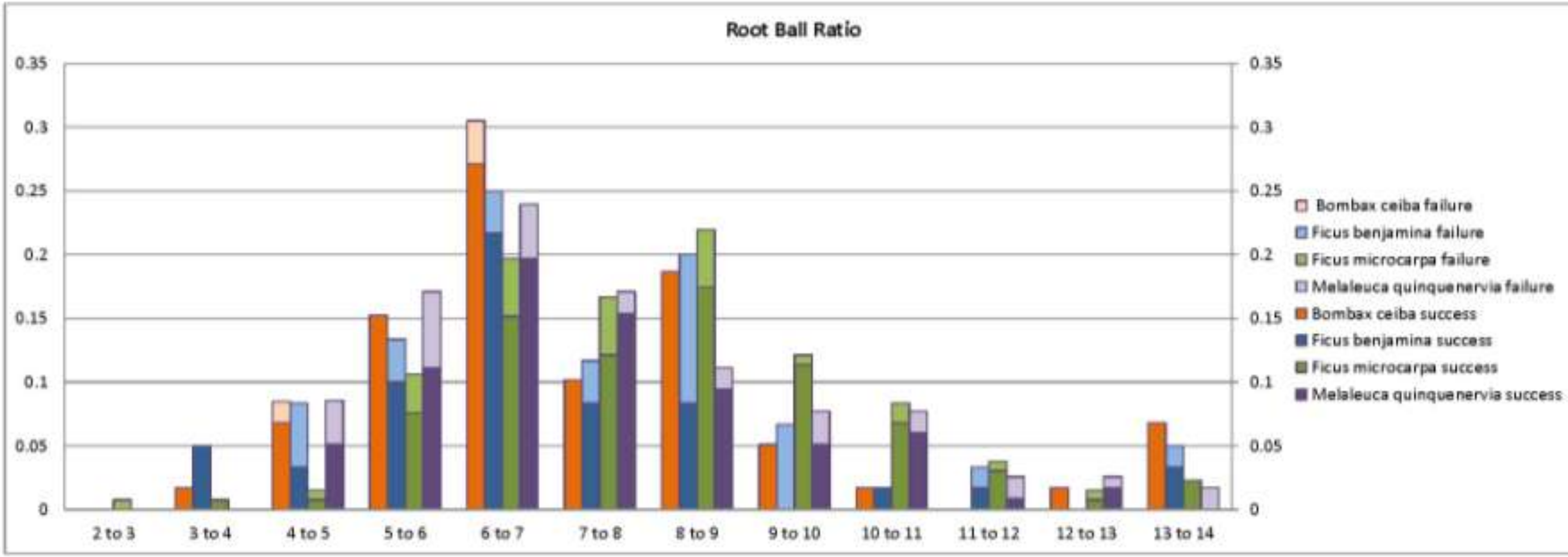
Melaleuca quinquenervia, strong correlation with location, height, form, pruning time and interval.
•Trees from pavement pits more likely to survive
•Higher failure rate for taller specimens and larger trunk diameter
•Higher success if pruning is undertaken in Sep – Dec, and pruning interval is shorter
•Better time for transplanting during March - August.

For all species, no significant correlation with root ball ratio and extent of canopy pruning.

Discussion

Transplanting success / failure (%) in relation to **'root ball ratio'**

Frequency distribution chart



- Standard root ball ratio: should result in a proportionate amount of root biomass being captured within the root ball, (so should not be a good predictor of the transplant failure or success).

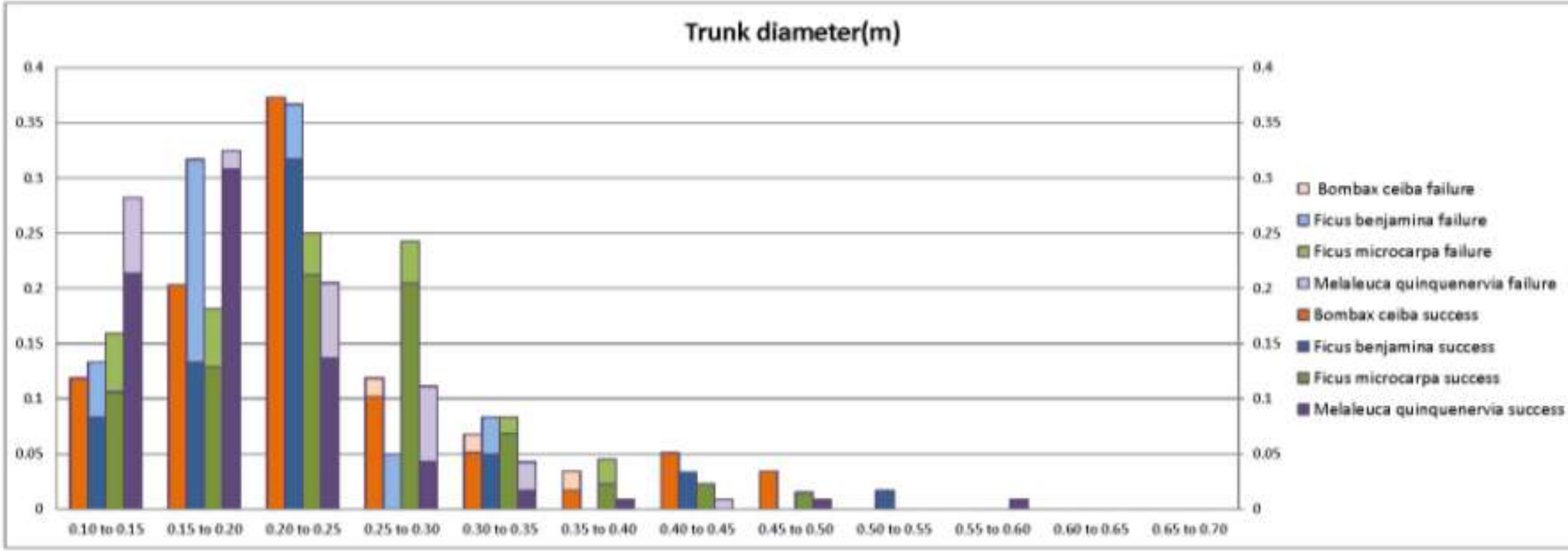
- Difficulties in forming the root balls resulted in a wide range of root ball ratios being achieved (3:1 to 13:1). Even then, this variable did not have a significant effect on success for three species, and only significant within the central range of ratios for the fourth species. Possibly due to highly constrained root pattern of street trees, and effective root pruning operations.

- Morphological adaptations of urban street trees to their poor soil environment may allow more of the root to be captured in the root ball making them more tolerant of transplanting. Preparatory root pruning can generate new roots around the actual root ball, making the dimensions of the root ball less important.

Discussion

Transplanting success / failure (%) in relation to **'trunk diameter'**

Frequency distribution chart



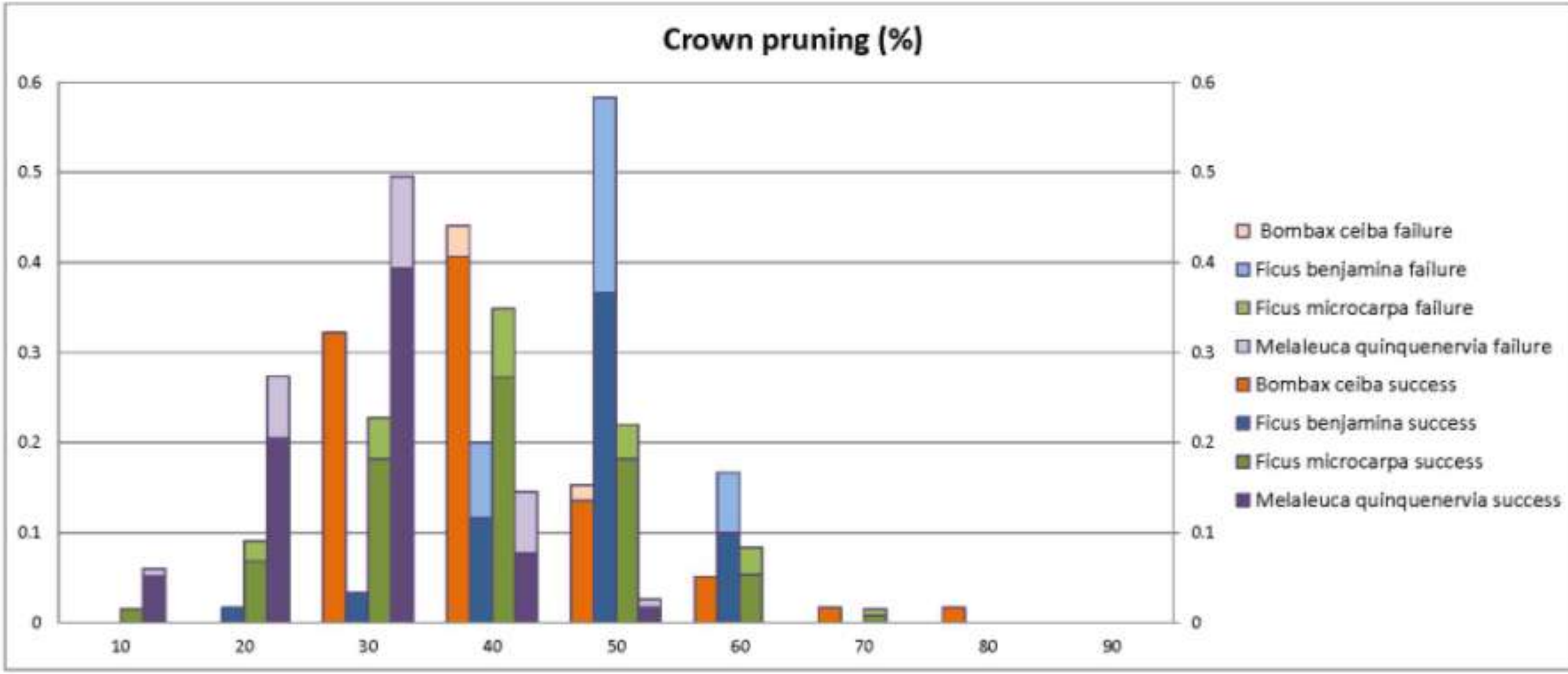
- Trunk diameter is a proxy for tree age, it might be expected that there would be an increasing likelihood of failure as size increased. Effect reduce by, use of a standard root ball ratio, and constrained root pattern of street trees.

- Slightly significant only for *Bombax ceiba* and *Melaleuca quinquenervia*. *Ficus spp*. trunk diameter not a determining factor.

Discussion

Transplanting success / failure (%) in relation to **'crown pruning'**

Frequency distribution chart



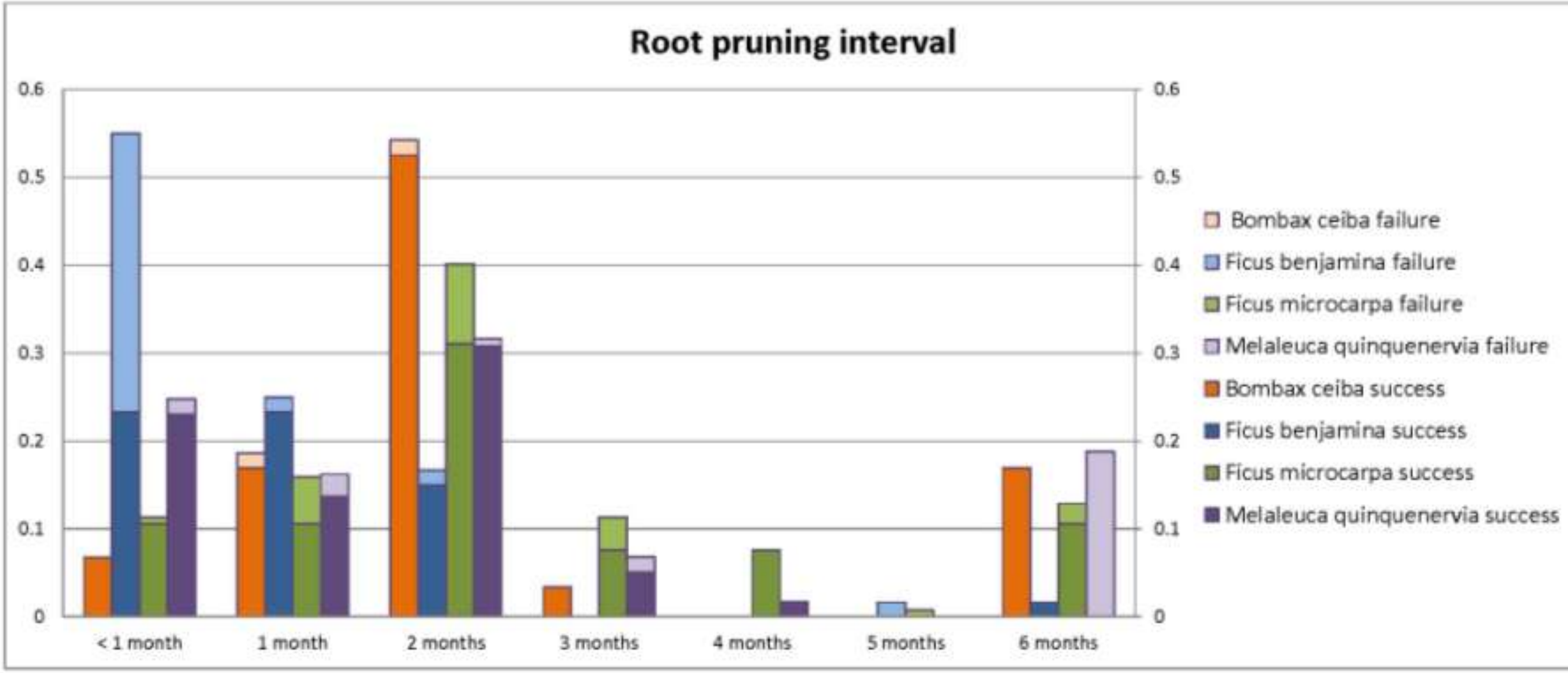
- Relationship between reduction in water absorbing capacity due to root pruning and reduction in potential transpiration water loss due to canopy pruning, impacts the ability of the tree to regain water balance after transplanting.

- Urban street trees lose less root than field grown trees due to their constrained growing conditions, and this is likely to reduce the influence of canopy pruning in transplanting.

Discussion

Transplanting success / failure (%) in relation to **'root pruning interval'**

Frequency distribution chart

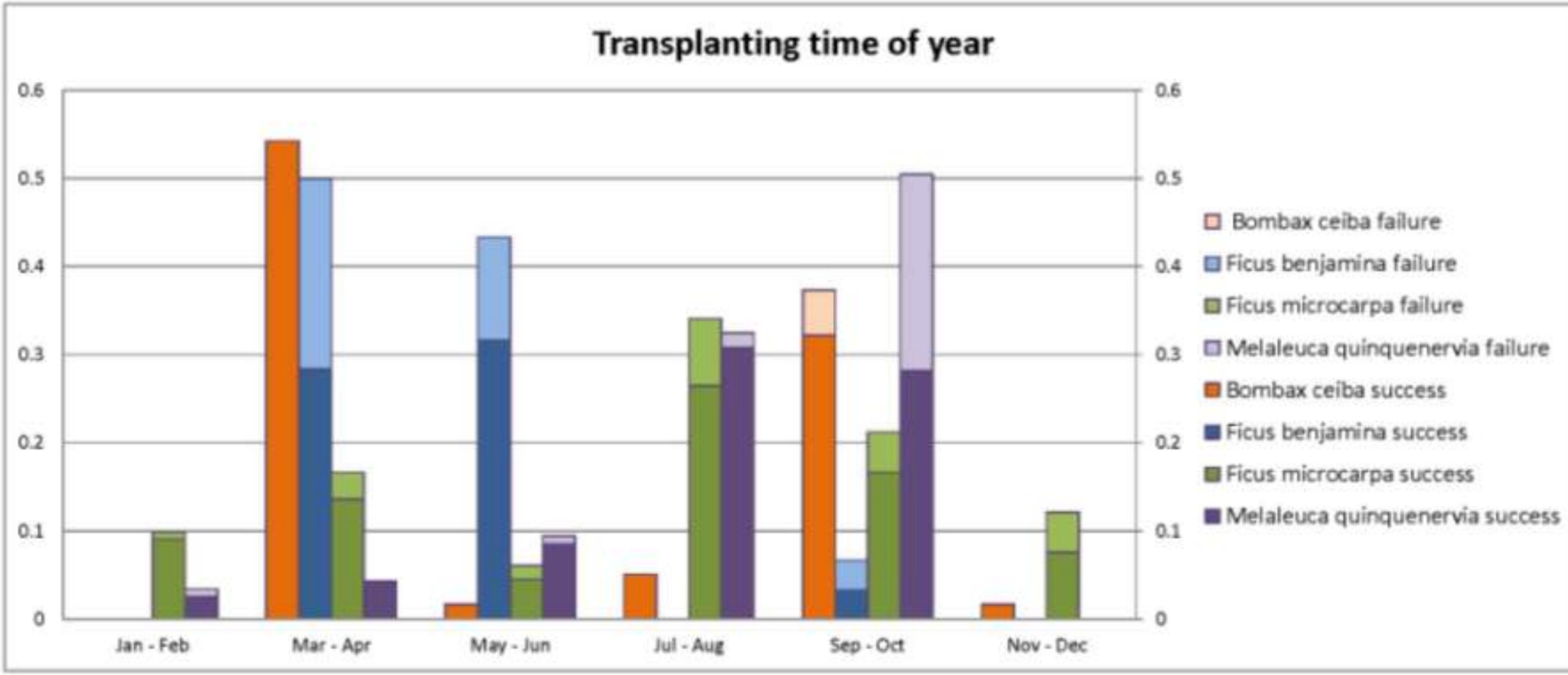


- Root pruning interval had been set in relation to the trunk diameter so not expected to be an indicator of success or failure.
- Other variables, such as pruning time of year, more influential.

Discussion

Transplanting success / failure (%) in relation to **'transplanting time of year'**

Frequency distribution chart



- *Melaleuca quinquenervia* – most failures in (Sep-Oct). This aligned with the root pruning interval results. The 6-month interval period placed the second root pruning within a period of active shoot growth. Species is deeper rooting, and mature specimens might also have been more heavily affected by the lifting operations than younger specimens.

Discussion
Other observations

Factors that were <u>not significant:</u>

•**Soils,** not an issue as long as the root ball was not allowed to desiccate i.e. speed of transplanting process - rapid replanting important

•**Existing health condition,** of the tree, even trees with previous structural damage transplanted well.

Trees within a street tended to be of the same species and size, and were prepared and moved at the same time. These sets of trees tended to react in the same way, suggest that 'transplanting factors' (e.g. timing, handling) might be more influential.

The re-establishment of all the trees in the same location, may have created a 'plantation' effect (one tree catches a cold, they all catch a cold).

Research Study
Statistical analysis

Regression analysis for the four species

Independent Variables	Constant	Species	Locat'n	Height	Trunk diameter	Form	Pruning time	Pruning interval	Transplant time	root ball ratio	Extent of Crown pruning
Standardized Coefficients	--	-0.240**	-0.041	-0.135*	0.236**	0.192**	0.209**	-0.108	-0.215**	0.040	-0.274**

The larger the coefficient the more effect of independent variable on dependent variable.

Species; trunk diameter; form; time of pruning; transplanting time; and extent of crown pruning, were all significant in determining the success / failure of the transplanting operation.

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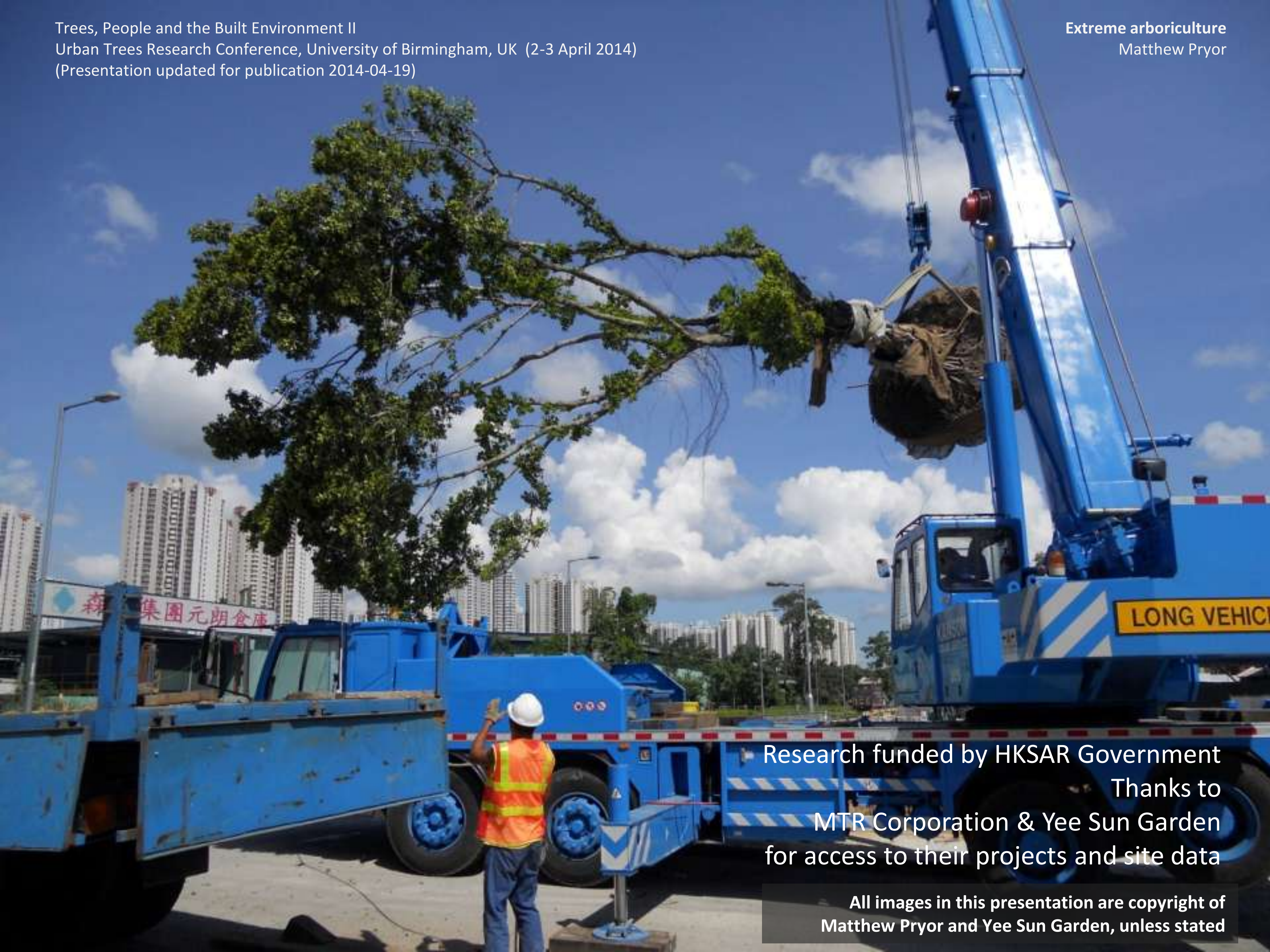

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